Recreational Vehicle Refueling Systems Test Strategy

- Reactive Organic Gas (ROG) emissions from RV refueling system = breathing loss + working loss
- Breathing loss = vented emissions from the fuel tank during storage + permeation from the fillneck hose during storage + permeation from the fuel hose during storage (Fig. 1)
- Working loss = refueling loss (displaced vapor from the receiving tank during refueling) + dripping loss from the nozzle when stop the refueling (Fig. 2)
- Permeation from the fillneck cap might be ignored if the cap is made of low permeation materials.
- Vented emissions from the nozzle might be ignored if it is a non-dripping nozzle (sealed well).
- Vented emissions from the pump might be ignored if it is a sealed steel pump.

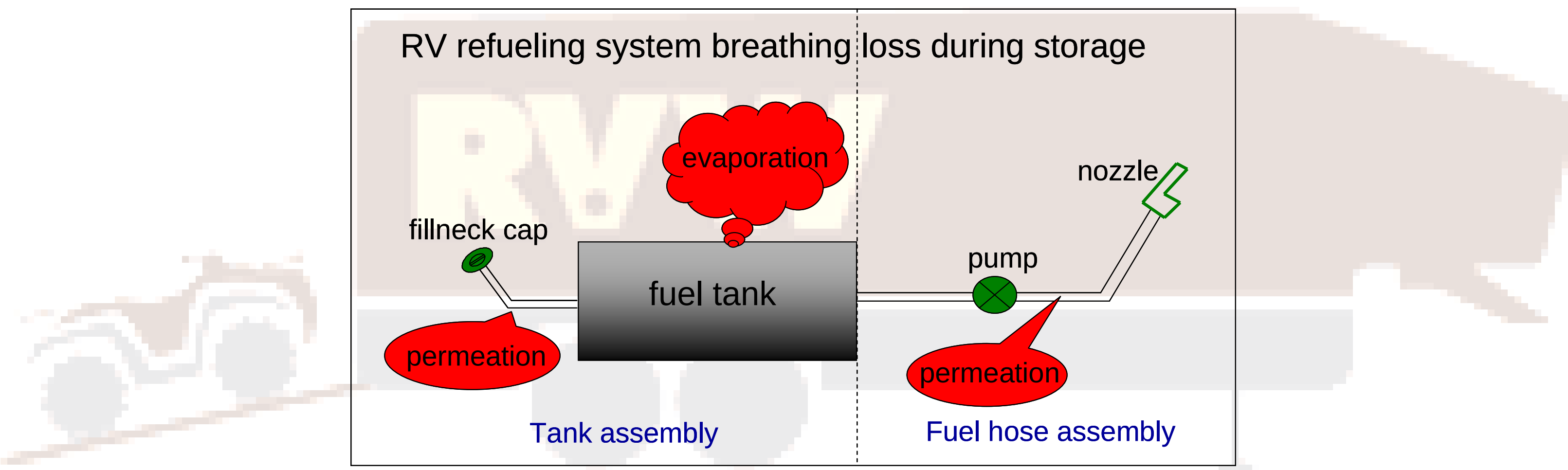

Figure 1. Schematic illustration of RV refueling system breathing loss during the storage.

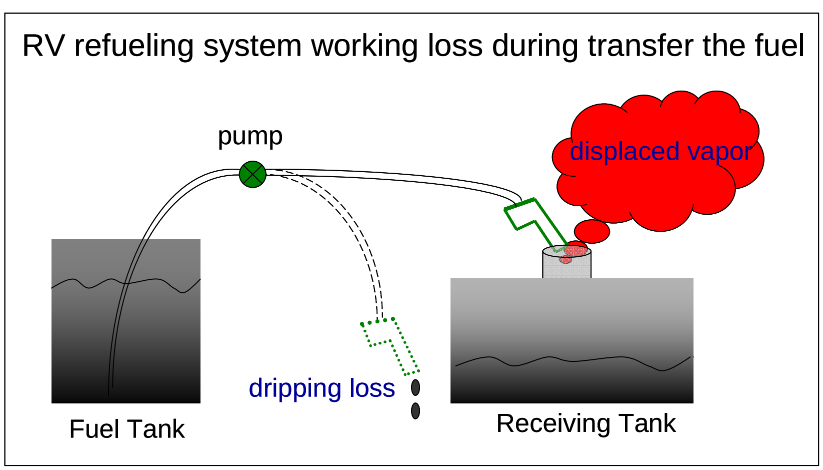

Figure 2. Schematic illustration of RV refueling system working loss during the refueling.

Recreational Vehicle Refueling Systems Test Protocol

Emissions from refueling systems and components

Run 1: Emissions test of the tank assembly (tank+fillneck hose+fillneck cap) only, plus EtOH impinger test (impinger sample each 24 hours)

This configuration will isolate the tank assembly (tank+fillneck hose+fillneck cap) from the fuel hose assembly (pre-hose+post-hose+nozzle), see Figure 1.

1. Drain the tank assembly and fuel hose assembly.
2. Remove the fuel hose assembly from the tank assembly at the pre-hose.
3. Plug the tank with a metal plug to ensure it is sealed.
4. Refuel the tank to 50% capacity with CaRFG3 E6 summer fuel.
5. Condition the tank assembly for 6 hours at 65 ºF.
6. Remove the carbon canister from tank rollover valve hose.
7. Conduct a one-day diurnal SHED test at 65ºF-105ºF-65ºF.
8. Repeat step 4-7 two times.

<u>Comments:</u>

Run 2: Emissions test of the fillneck hose+fillneck cap, plus EtOH impinger test

This configuration will exclude the emissions from the rollover valve. Therefore, subtracting Run 2 from Run 1 will determine the emissions from the rollover valve.

1. Drain the tank assembly.
2. Remove the rollover valve and rollover valve hose from the tank.
3. Seal the rollover valve with a metal cap or a metal plug at the top of tank.
4. Refuel the tank to 50% capacity with CaRFG3 E6 summer fuel.
5. Condition the tank assembly for 6 hours at 65 ºF.
6. Conduct a one-day diurnal shed test at 65ºF-105ºF-65ºF.
7. Repeat step 4-6 two times.

<u>Comments:</u> Sealing the tank causes high pressure at higher temperatures. Serious leaks may happen at the screw location on the top of the tank and at the gas cap connection area. Permeation through fillneck hoses (thin and thick) may increase twice under normal pressure. Compared to the fillneck hose permeation, the leakage from the screw location and the gas cap connection area are the major problems.

Run 3: Emissions test of the tank assembly with "low permeation" fillneck hose, plus EtOH impinger test

1. Drain and refuel the tank to 50% capacity with CaRFG3 E6 summer fuel.

2. Wrap both fillneck hoses with multiple layers of aluminum tape and make tight with clamps. The purpose is to reduce the permeation emissions from the fillneck hoses.
3. Condition the tank system for 6 hours at 65 ºF.
4. Conduct a one-day diurnal SHED test at 65ºF-105ºF-65ºF.
5. Repeat steps 1-4 two times.

Comments:

Run 4: Gravimetric test of permeation from the refueling hose assembly (pre-hose +post-hose+nozzle), combining the gravimetric test with SHED temperature profile.

1. Label each hose as indicated.
2. Provide metal caps of appropriate size to seal each hose.
3. Print out “Refueling Hose Testing Results E6 forms” (see the attachment) for each hose as indicated.
4. This protocol combines a gravimetric procedure with the use of the SHED to maintain a constant steady-state temperature of 73°±4°F.
5. Two types of tests will be conducted per hose; one at 50% fuel capacity, and the other at 100% fuel capacity.
6. All ROG data is an extrapolation from the sample weight loss.

Part - I : This protocol assumes that the user would store the container with fuel in the hose. It is assumed that the amount of fuel in the hose is 50% of the hose capacity.

Before you start: Complete Section I of the “Refueling Hose Testing Results E6 form”. Make sure to recalibrate the electronic balance before using for the first time. Reset the balance to “0” every time before weighing.

1. Determine the “empty” weight of each hose.
    a. Hoses with a nozzle: cap the open end with the appropriate size metal cap (purchased from a local hardware store vendor). The other end has a nozzle attached and does not need to be capped.
    b. Hoses that have no nozzle - cap both ends.
    c. Record the weight in the form under “Hose Weight: Initial-Empty”.
2. Determine weight after 30-day (100%) soak:
    a. Determine the capacity of the hoses (in mL) by measuring the amount of fuel placed in the hose, and record on the test form under “Hose Capacity”.
    b. Slowly fill with CaRFG3 E6 summer fuel to avoid the generation of air bubbles. Place the fully-filled hoses loosely coiled on a wire shelf in the storage shed for 30 days. Do not stack the hoses on top of each other; doing so will limit the surface area being saturated.
    c. Use a J-type thermocouple and a chart recorder or other means of measurement to accurately measure the daily temperature (a minimum of three times daily) within the storage shed during the 30-day soak.
    d. Inspect each hose individually during the soaking period. If leakage occurs, seal fitting threads with sealant (such as seal-all or other gas resistant sealant).
    e. Drain the hoses after soaking for 30 days. Measure the volume of the fuel left and record the fuel color property changes.

f. Weigh each hose and record the weight of the hose in the form under "Hose Weight: After 30-day soak-empty".

3. SHED test after 30-day soak-empty"
   a. Slowly fill each hose to 50% capacity with CaRFG3 E6 summer fuel to avoid the generation of air bubbles. Record the volume of the fuel (in mL) placed in the hose under "Hose Test Volume" in the "50% capacity" section.
   b. Weigh the hose and record the weight of the hose in the form under "Hose weight: Pre-condition" in the "50% capacity" section.
   c. Place the hoses on a wire shelf in the SHED, loosely coiled, (hose coils should not touch each other). Do not stack the hoses on top of each other, doing so will limit the surface area being saturated.
   d. Pre-condition the hoses for <u>6-24 hours</u> at 73°±4°F.
   e. Weigh each hose after pre-conditioning. Record the weight under "Gravimetric Data" in the weight column, "Day-1 Initial" row in the "50% Capacity" section. Record the date and time of the reading. Record the laboratory temperature, barometric pressure, and humidity at the time of weighing.
   f. Replace in the SHED to complete first 24-hour interval.

4. Run the SHED for 10 (or more) 24-hour intervals (to maintain constant temperature only, no ROG results needed).
   a. Inspect each hose individually for leaks before each weighing to make sure that there are no visible leaks.
   b. Weigh each hose at the end of every 24-hour interval. Record the date and time of the reading. Record the laboratory temperature, barometric pressure, and humidity at the time of weighing.
   c. After weighing the hoses, put them back into the SHED as quickly as possible. There is no pre-conditioning.
   d. Repeat step 4 and keep recording until a stable weight loss per day is obtained for a <u>minimum of three or more</u> consecutive days.

<u>Comments:</u> The connection between the nozzle and the post-hose were retained as it was from the manufacture. No leakage was found at the connection area of nozzle and hose. The ends of the hoses without nozzles were capped by the metal caps with the sealant (seal-all gas&oil resistant) sealed. No leakage was found at the connection of the hose and metal cap.

<u>Part – II:</u> This protocol assumes the user does not empty the hose prior to storage. It is assumed that the amount of fuel in the hose is 100% of the hose capacity.

1. SHED Test (100%)
   a. Slowly begin to refill hoses to 100% capacity with CaRFG3 E6 summer fuel as quickly as possible after emptying. Record the volume of fuel (in mL) placed in the hose under "Hose Test Volume" under the "100% Capacity" section.
   b. Weigh the hose and record the weight of the hose in the form under "Hose weight: Pre-condition" in the "100% Capacity" section.
   c. Place the hoses on a wire shelf in the SHED, loosely coiled, (where hose coils are not touching each other).
   d. Pre-condition the hoses for 6-24 hours at 73°±4° F.
   e. Weigh each hose after pre-conditioning. Record the weight under "Gravimetric Data" in the weight column, "Day-1 Initial" row under the "100% Capacity"

section. Record the date and time of the reading. Record the laboratory temperature, barometric pressure, and humidity at the time of weighing the hose. Replace in the SHED to complete first 24-hour interval.

2. Run the SHED for 10 (or more) 24-hour intervals (to maintain constant temperature only, no ROG results needed)

   a. Weigh each hose at the end of every 24-hour interval. Record the date and time of the reading. Record the laboratory temperature, barometric pressure, and humidity at the time of weighing.
   b. After weighing the hoses, put them back into the SHED as quickly as possible. There is no pre-conditioning.
   c. Repeat step 2 until a stable weight loss per day is obtained for a <u>minimum of three or more</u> consecutive days.

3. Drain the hoses after the test. Weigh the volume of the fuel left and record the fuel color property changes.

<u>Comments:</u> No leakage happened in the test.

4. Fully fill and soak the hoses with CaREF3 E6 summer fuel for future tests.

<u>Additional Information</u>

1. When it is not possible to weigh on a 24-hour interval (weekends), a weighing can be taken at the next possible 24-hour interval and the weight loss results will then be averaged over the missed 24-hour interval(s).
2. Visually inspect each hose when handling the hoses during the entire test procedure. If leakage occurs, make note and seal fitting threads with a proper sealing method.

Run 5: Emissions test of the refueling system (tank assembly + hose assembly)

This configuration will test the diurnal emissions from the whole unit.

1. Drain and refill the tank to 50% capacity with fresh CaRFG3 E6 summer fuel.
2. Recirculate the fuel through the fuel filler hose back into the fuel tank for 1 minute.
3. Lay the filler nozzle on the refueling tank frame below the fuel tank level to retain fuel in the fuel filler hose.
4. Condition the refueling tank system for 6 to 36 hours at 65ºF.
5. Conduct a one-day Diurnal SHED Test at 65ºF-105ºF-65ºF.
6. Repeat steps 1-5 two times.

<u>Comments:</u>

Run 6: Control technology test (with carbon canister) of the refueling system, plus EtOH impinger test (impinger sample each 24 hours)

1. Drain and refuel the tank to 50% capacity with CaRFG3 E6 summer fuel.
2. Recirculate the fuel through the fuel filler hose back into the fuel tank for 1 min.

3. Lay the filler nozzle on the refueling tank frame below the fuel tank level to retain fuel in the fuel filler hose.
4. Purge the #1 tank carbon canister with 300 bed volumes of dry air through the canister at the canister manufacturer's recommended purge rate 22.65 L/min.
5. Condition the refueling tank system for 6 hours at 65 ºF.
6. Connect the rollover valve hose to the canister.
7. Conduct a 7-day diurnal SHED test at 65ºF-105ºF-65ºF.
8. Weigh the canister before and after the 7 day-diurnal SHED test.

Comments:

Run 7. Control technology test (with carbon canister, low permeation hose) of the refueling system, measure the pressure inside the tank.

1. Replace the refueling hoses (pre-hose and post-hose) with low permeation hoses.
2. Replace the roll over hose with low permeation hose.
3. Wrap the fillneck hoses with multiple layers of aluminum tape and make tight.
4. Put a digital pressure gauge on the top of refueling tank to measure the pressure inside the tank.
5. Drain and refill the tank to 50% capacity with CaRFG3 E6 summer fuel.
6. Recirculate the fuel through the fuel filler hose back into the fuel tank for 1 min.
7. Lay the filler nozzle on the refueling tank frame below the fuel tank level to retain fuel in the fuel filler hose.
8. Load the ECI#1 carbon canister to full 2g breakthrough and purge it with 300 bed volumes of dry air through the canister at 22.65 L/min (0.8 cfm) purge flow rate.
9. Condition the refueling system for 6 hours at 65 ºF. Record the pressure inside the tank every 2 hours.
10. Weigh the carbon canister before connect to the tank.
11. Connect the rollover valve hose to the carbon canister.
12. Conduct a 7-day diurnal SHED test at 65ºF-105ºF-65ºF with the canister on. Record the pressure under 65 ºF, 85 ºF, 105 ºF, 85 ºF, 65 ºF in each one diurnal day (Records in non-working hours could be missed).
13. Weigh the carbon canister after 7-day diurnal SHED test.

Comments:

Refueling loss measurement:

1. Deriving the formula to estimate refueling losses

To derive the formula for the mass of gasoline that will be displaced from the receiving tank when refueling from the fuel tank, the general vapor density formula[1] is used:

$Wv = MvPv / RT$

Where:

Wv = vapor density, lb/ft3

Mv = vapor molecular weight, lb/lb-mole;

Note: vapor molecular weight is related to RVP; so for gasoline with RVP 7 to 8.3, the molecular weight is 68 (AP-42, Table 7.1-3).

R = the ideal gas constant, 10.731 psia ft^3/lb-mole deg R

Pv = vapor pressure at daily average temperature, psia

T = daily average temperature, deg R

Note: this is absolute temperature in degrees Rankine (R), not Fahrenheit: to convert to deg R from deg F, add 459.69.

Since density (Wv) = m / V, $m = VvMvPv / RT$

Where:

m= mass of gasoline displaced as vapor (lb)

Vv = volume of gasoline displaced as vapor (ft3)

2. Calculating an estimated emission factor for displaced vapor:

Assumptions:

The volume of gasoline vapor displaced is equal to the volume of gasoline pumped out of the fuel tank into the receiving tank. Ambient temperature is 85 °F

Gasoline RVP = 7, Pv = 5.7 psi at 85 °F

Vapor molecular weight = 68

Conversions:[2]

1 gal gasoline =0.13 ft^3

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[1] From AP-42, page 7.1-64, and other references consulted
[2] Reference website: http://www.onlineconversion.com/volume.htm

T = 85 deg F = 545 deg R (absolute temp.)

1 lb = 453.59 grams

Plugging the values into above formula gives:

Mass of gasoline lost as vapor = VvMvPv /RT= (0.13 x 68 x 5.7) /(10.731 x 545) = 0.00862 (lbs) = 3.9 grams

Therefore 1 gallon of gasoline pumped into a receiving tank results in 3.9 grams of gasoline lost as displaced vapor at 85 °F ambient temperature.

Emission factor for refueling losses (displaced vapor losses) = 3.9 gram/gal vapor (gasoline RVP 7, at 85 deg F).

Dripping loss measurement:

Dripping loss from the refueling nozzle depends on users how to terminate refueling process. From ARB staff, about 1 ml gasoline drops from the nozzle when holding the nozzle in the fillneck of a receiving tank for a few seconds after refueling; about 30 ml liquid gasoline drops from the nozzle if pull the nozzle out of the fillneck immediately after refueling. With the volume of 1-30ml gasoline, ARB staff calculates the mass of the dripping loss: [3]

Mass of 1 ml CaRFG summer fuel E6: 0.71 grams

Mass of 30 ml CaRFG summer fuel E6: 21.8 grams

[3] Gasoline RVP 7: vapor molecular weight at 60 F M_V=68 lb/mole, Liquid density at 60 F W_L=5.6 lb/gal